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HEAVY FLAVOUR PRODUCTION AT HERA

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A selection of topics on open heavy quark production at *HERA* are reviewed here. Measurements of charm fragmentation parameters will be presented together with developments in the study of D^* di-jet angular distributions. Charm production in deep inelastic scattering (*DIS*) is also discussed. Finally we deal with recent measurements of b cross sections using impact parameters in both *DIS* and photoproduction regimes.

1 Introduction

Colliding ep at a center of mass energy of $\sqrt{s} = 296 - 318$ GeV *HERA* provides an interesting environment for testing *QCD* predictions on heavy quark production. The virtual photon emitted by the incoming lepton provides a clean probe which, interacting with quarks and gluons in the proton, can initiate hard processes. The scale of the *QCD* interaction spans over a wide range of values which are under direct experimental control. This report will concentrate on a selection of some recent measurements performed by the *H1* and *ZEUS* collaborations with a focus in particular on *open* c and b quark production in both *deep inelastic scattering* (*DIS*: $Q^2 > 1$ GeV^2) and *photoproduction* ($Q^2 \sim 0$ GeV^2) regimes.

2 Charm production

2.1 Fragmentation tests

The luminosity accumulated in the first phase of *HERA* running (1992-00, ~ 130 pb^{-1}) allows the study of particular decay channels which provide measurements of some phenomenological parameters used to describe charm fragmentation. *ZEUS* recently presented measurements of the branching fraction $f(c \to D^+_{s1})$ [a] [1], the *strangeness suppression factor* [2] γ_s (a parameter of Lund string model which rules the relative production of *strange* and non strange D mesons) and the $P_v = V/(V + PS)$ ratio [3] relating the production of the vector (spin-1) to the pseudoscalar charmed mesons. The values shown in tab.1 give support to the hypothesis of *charm fragmentation universality*: the c quark hadronizes in the same way in e^+e^- and ep interactions.

[a] $D^{\pm}_{s1}(2536)$ is one of the $L = 1$ states of the cs system

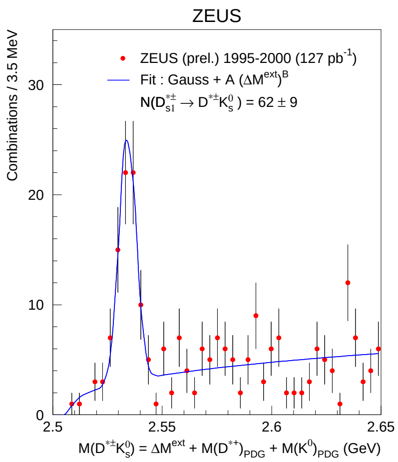

Table 1: c fragmentation in ep and e^+e^-

	ep	$\mathbf{e^+e^-}$
$f(c \to D^+_{s1})$	$(1.24 \pm 0.18^{+0.08}_{-0.06} \pm 0.14\ (b.r.))$ %	$(1.6 \pm 0.4 \pm 0.3)$ % [4] $(0.94 \pm 0.22 \pm 0.07)$ % [4]
$\frac{\sigma(D_s)}{\sigma(D^*)}$	$0.41 \pm 0.07^{+0.02}_{-0.05}$	0.43 ± 0.04 [2]
$\gamma_s = P_s/P_{u,d}$	$0.27 \pm 0.04^{+0.02}_{-0.03} \pm 0.07\ (b.r.)$	0.26 ± 0.03 [2]
$P_v = D^*/(D^* + D)$	$0.546 \pm 0.045 \pm 0.028$	0.57 ± 0.05 [5] 0.595 ± 0.045 [5]

Figure 1: The $D^\pm_{s1}(2536)$ signal seen in the decay $D^\pm_{s1} \to D^{*\pm}K^0_S$ with $D^{*\pm} \to D^0\pi^\pm$ and $D^0 \to K^\mp\pi^\pm$

2.2 Di-jet angular distributions in D^* events

Di-jet angular distributions, depending on the spin of the exchanged propagator, are an interesting tool one can use to gain insight into parton dynamics. Charm is produced in *direct* processes essentially through the q-exchange diagram $\gamma g \to c\bar{c}$ (*Boson Gluon Fusion*) (fig.2, top right) while *resolved* production receives contributions also from g-exchange processes like the one shown in the bottom right part of fig.2 ($cg \to cg$). The distribution of the variable $\cos\theta^* = \tanh\frac{\eta^{jet1}-\eta^{jet2}}{2}$, θ^* being the angle between the beam axis and the di-jet axis in the di-jet rest frame, has been studied for two different samples enriched in direct or resolved processes. This separation is defined experimentally by cutting on the jet-based observable $x^{OBS}_\gamma \equiv \sum_{jets} E_T e^{-\eta}/2yE_e$ which is an estimator of the fraction of γ momentum entering in the hard scattering. Preliminary results from *ZEUS* [6], fig.2, show a steep angular rise for the resolved enriched sample ($x^{OBS}_\gamma < 0.75$) towards high $|\cos\theta^*|$ in marked contrast to a gentler behaviour in the direct enriched sample ($x^{OBS}_\gamma > 0.75$). The solid histograms are obtained with the *PYTHIA LO* Monte Carlo. The result is consistent with the fact that the direct processes proceed via q-exchange (spin 1/2 propagator $\sim (1-|\cos\theta^*|)^{-1}$ is expected) while resolved processes are dominated by gluon exchange (spin 1 propagator $\sim (1-|\cos\theta^*|)^{-2}$ *Rutherford scattering*). This observation is consistent with an important gluon exchange contribution which is directly associated to the presence of c-excitation processes in the quasi-real photon.

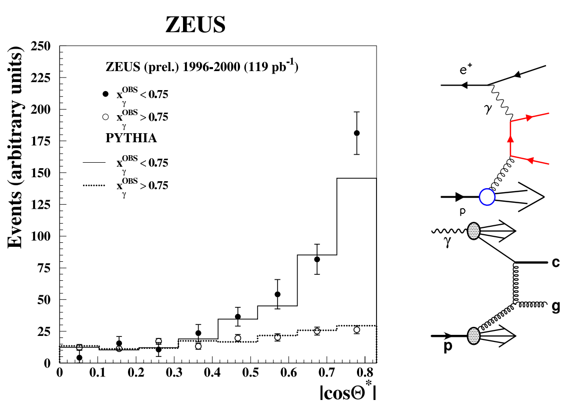

Figure 2: $dN/d|\cos\theta^*|$ distributions in D^* di-jet ($E_T >$ 5 GeV) events. The distributions for resolved (black dots) and direct (open dots) events have been normalized to each other in the lowest four bins.

2.3 Open charm in DIS: contribution to the F_2 structure function

Both *H1* and *ZEUS* measured F^c_2, the charm contribution to the F_2 proton structure function [7,8,9]: $\frac{d^2\sigma^{ep\to ecX}}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4}(1+(1-y)^2)\cdot F^c_2(x,Q^2)$. Two procedures for tagging charm have been exploited: the presence of $D^{*\pm}$ mesons [7,8] or electrons [9] from c semi-leptonic decays. After the signal has been identified the numbers of events in bins of x and Q^2 are converted into an inclusive charm cross section extrapolating to the full phase space by means of Monte Carlo generators. Theoretical models are then used to relate the measured cross section to F^c_2. The plot in fig.3a shows how F^c_2 exhibits evident scaling violations (i.e. Q^2 dependence). The ratio of F_2^c to the inclusive F_2 is presented in fig.3b as a function of x in Q^2 bins. Charm contribution to DIS is definitely sizeable ranging from ~ 10 % of the inclusive F_2 at low Q^2 up to $\sim$ 40% at $Q^2 \sim 500$ GeV and $x \sim 0.01$. This asymptotic contribution at high Q^2 is consistent with the picture in which the c quark can be treated as any other massless quark ($Q^2 >> m_c$), the relative contribution following just from a simple charge counting rule. The drop of F_2^c/F_2 at high x is related to the steep decrease of the proton gluon density with x leading to a suppression of gluon initiated processes. The *HVQDIS* [10] program which is based on *DGLAP* evolution equations, evaluating the *BGF* diagram at *NLO*, provides an overall satisfactory description of F_2^c data. In addition to *HVQDIS* *H1* uses the Monte Carlo program *CASCADE* [11] which implements the so called *CCFM* evolution scheme. Using this approach the description of data improves at lower values of x and Q^2 (not shown).

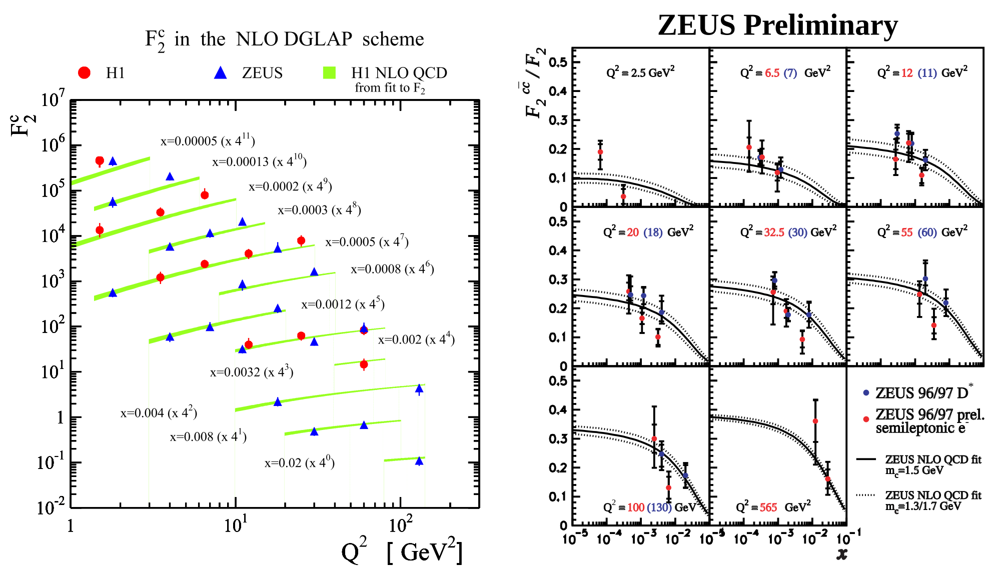

Figure 3: charm contribution to F_2

3 Beauty production

Both *H1* and *ZEUS* have published results on b production [12,13,14,15,16]. The basic sample used for this measurement consists of events with jets and moderately high momentum leptons. Due to the high b quark mass, the lepton from b semi-leptonic decay tends to emerge at higher transverse momenta with respect to the jet axis (p_T^{rel}) than in the case of c or light quarks decays. This feature allows signal extraction on a statistical basis by fitting data with Monte Carlo distributions. The latest *H1* results benefit also from the presence of a micro-vertex detector information. The impact parameter distribution of candidate μ tracks (δ) is endowed with an asymmetric tail at positive values (i.e. vertex is downstream of the associated jet) coming from the presence of long living particles. This independent signature provides results which are in good agreement with those obtained using the p_T^{rel} method. The distributions of the two observables δ and p_T^{rel} for a *DIS* selection ($2 < Q^2 < 100$ GeV^2, $0.05 < y < 0.7$, $p_T^\mu > 2$ GeV/c, $30° < \theta^\mu < 135°$) are shown in fig.4. The measured cross section $(39 \pm 8 \pm 10)$ pb[b] lies significantly above the value of *HVQDIS NLO* calculation (11 ± 2) pb. The *LO* Monte Carlo *AROMA* gives a prediction of 9 pb and *CASCADE* expects 15 pb. The *NLO* theoretical error has been evaluated by varying the renormalization and factorization scales, m_b and fragmentation parameters. Similarly *H1* measured the cross section at low Q^2. In the following kinematic

[b] In the following first quoted error is statistical and the second systematic.

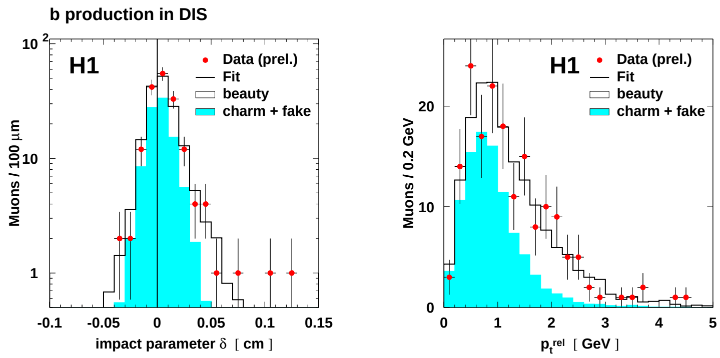

Figure 4: b in *DIS*: the solid histogram is the fit to data. It is obtained by adding the fitted b signal ($f_b = (43 \pm 8)$ %) to the shaded component which represents the c + fake muons background.

region: $Q^2 < 1$ GeV^2, $0.1 < y < 0.8$, $p_T^\mu > 2$ GeV/c, $30° < \theta^\mu < 135°$ the measured cross section is $\sigma_{vis} = (160 \pm 16 \pm 29)$ pb. When combined to a previous measurement which used just the p_T^{rel} variable the result becomes: $\sigma_{vis} = (170 \pm 25)$ pb which is well in excess with respect to various expectations which amount to 38, 67, (54 ± 9) pb for the *AROMA*, *CASCADE* and *NLO FMNR* calculations respectively. The first measurement of b differential cross sections [16] has also been recently carried out by *ZEUS*. Visible cross sections in the muon transverse momentum and pseudo-rapidity have been calculated. The signal component was determined in each bin through a fit to the p_T^{rel} distribution. In this case *PYTHIA* expectation is not far from data with some deficit at high μ pseudo-rapidities where excitation contribution is expected to be large. *HERA* results on b cross sections are summarized in fig.5. The ratio of the measured cross sections to the predictions at *NLO* is plotted for different Q^2 regimes. The inner (outer) error bands represent the statistical (total) experimental error, the shaded band covers the theoretical uncertainty.

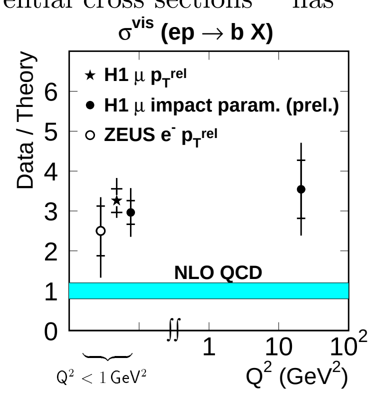

Figure 5: b results from *HERA*: data/theory.

Acknowledgments

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